LINCOLN UNIVERSITY
Centre for Land, Environment & People

LEAP Research Report
No. 55

A snapshot of water quality from sampling freshwater invertebrates in Purau stream, Lyttelton Harbour/Whakaraupō

Report for Environment Canterbury

Kate Marshall

February 2021

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Cover photo: Purau Bay, Lyttelton Harbour/Whakaraupō. Source: Jo, 2009, https://flic.kr/p/6gCYFy

Contents

List of Figures

List of Tables

Summary

Whaka-Ora Healthy Harbour is a partnership between Te Hapū o Ngāti Wheke, Te Rūnanga o Ngāi Tahu, the Lyttelton Port Company, Environment Canterbury and Christchurch City Council[1]. The partnership is working to restore the ecological and cultural health of Lyttelton Harbour/Whakaraupō in conjunction with resident groups.

The restorative focus includes: increasing indigenous biodiversity; protecting and restoring mahinga kai values; providing a safe place for recreation; and protecting the harbour for future generations. Currently, issues relating to the health of the harbour have been identified, such as sedimentation, erosion, high nutrient levels, and bacterial contaminants, which cumulatively impact on indigenous biodiversity and coastal water quality.

Purau Bay is one of the large bays located on the southern side of Lyttelton Harbour/ Whakaraupō, located also within the wider Banks Peninsula/Te Pātaka o Rākaihautū area. Purau Bay has a permanently flowing stream that winds its way through a variety of land uses, including indigenous vegetation, pastoral farmland, and residential properties before discharging into the harbour. This study takes a snapshot of the environmental quality of Purau Stream by examining the diversity of aquatic invertebrates as an indicator of the stream health at two sites along the stream. The results from the macroinvertebrate community index (MCI) were compared to Te Wharau catchment in nearby Orton Bradley Park, where contemporaneous data were also collected from two locations within the stream.

The condition of both streams was assessed as being in overall good health, although the MCI was lower at the Purau bridge site compared to the upstream site and the Te Wharau stream sites. Previous water quality sampling by Environment Canterbury at the bridge indicates that although the current condition is classified as good, the long-term trend is may be declining water quality.

These results contribute to informing progress towards the partnership's long-term plan for these streams, which is "to enhance the riparian margins and water quality to a state where sensitive species are present": The current condition of both streams is contextualised within past changes to the catchment, through the presentation of a brief overview of historical events.

[1] https://www.healthyharbour.org.nz/

Chapter 1. Introduction

1.1. Whaka-ora Healthy Harbour Programme

The Whaka-ora Healthy Harbour Catchment Management Plan was developed during development of the Lyttelton Port Recovery Plan. The communities around the harbour wanted agencies and the community to help improve the health of the harbour. This resulted in a partnership between five agencies, Te Hapū o Ngāti Wheke, Te Rūnanga o Ngāi Tahu, the Lyttelton Port Company, Environment Canterbury and Christchurch City Council.

Launched in 2018, the Whaka-ora Healthy Harbour plan is supported by the five partners to help the community achieve the action points. The main aim of the plan is to “restore the ecological and cultural health of Whakaraupō/Lyttelton Harbour as mahinga kai” (Whaka-ora, n.d). This includes increasing biodiversity, safeguarding mahinga kai values, providing a safe place for recreation and protecting the harbour for future generations.

Streams are one of the focal points in the Whakaraupō/Lyttelton Harbour Catchment Management Plan, as there are five permanently flowing streams discharging into it. These streams are in excellent condition in the upper reaches but start to deteriorate as they get closer to the harbour. To help improve the water quality the plan aims to focus on fencing off the stream to stock and the planting of the riparian zone.

Whaka-ora Healthy Harbour have identified Purau Bay as an area of significant recreation, ecological and mahinga kai value. Issues relating to the health of the harbour, such as sedimentation, erosion, water pollution and decreasing indigenous biodiversity have also been identified as problems within the catchment. Purau Stream has a number of landowners who are working together to help restore the catchment (K, Banwell, personal communication, November 2020).

Whaka-ora Healthy Harbour and Lincoln University jointly funded a summer research scholarship to investigate the environmental quality of Purau Stream in late 2020/early 2021. Results from sampling for aquatic invertebrates are reported here along with a discussion about the stream health. The results are compared with Te Wharau stream, which is a separate catchment to the south (Figure 1).

1.2. Why aquatic Invertebrates?

There are many abiotic and biotic factors that influence the composition of aquatic invertebrate communities in streams and rivers (Wright-Stow & Winterbourn, 2003). These factors can include pH, temperature, substrate composition and species interactions. As environmental factors change over time, this can affect the species inhabiting the streams. Sensitive species, such as Ephemeroptera (mayfly), Trichoptera (caddisfly) and Plecoptera (stonefly), can be replaced by more pollution tolerant species such as Oligochaeta (worm) and Littorinimorpha (snail), as water quality deteriorates (Wright-Stow & Winterbourn, 2003).

The Macroinvertebrate Community Index (MCI) can be used to indicate the health of freshwater ecosystems in New Zealand[2], as the invertebrate species present in a waterway affect the outcome of the MCI calculation. Species such as mayfly, caddisfly and stonefly are more sensitive to changes in their environment and contribute a higher score towards to the MCI. Whereas, species such as worms or snails are more tolerant of polluted waterways and can lower the MCI (Landcare Research, n.d). An MCI score higher than 120 indicates excellent stream health, whereas a score of 80 or below indicates poor stream health (Gray, 2013).

Aquatic invertebrates are a common group of organisms to monitor for waterway health, as they are relatively easy to measure over time using standard procedures, their sampling being relatively non-destructive of the environment, inexpensive and biologically relevant (Cairns, McCormick and Niederlehner, 1993).

1.3. Aim of research

This study seeks to investigate the environmental quality of Purau Stream with MCI scores at a point in time. The sampling is augmented with an assessment of instream habitats and substrata, and overhead canopy cover. The results are compared to Te Wharau Stream catchment in Orton Bradley Park (Figure 1). An overview of historical changes to the Purau catchment is also presented to assist in contextualising current conditions.

Figure 1: Location map of study sites in Purau (red star) and Te Wharau (yellow star) catchments.

[2] https://www.lawa.org.nz/learn/factsheets/benthic-macroinvertebrates/

Chapter 2. Catchment Attributes

2.1. Climate and Rainfall

Purau Bay is one of many large bays located on Banks Peninsula/Te Pātaka o Rākaihautu on the south shore of Lyttelton Harbour/Whakaraupō, surrounded by Mount Herbert (920 m), the highest Banks Peninsula peak, and Mount Evans (Figure 1). Rainfall recorded at the closest weather station at Coopers Knob is around 730 mm per year (Environment Canterbury, n.d). Winter brings snow above 600 m, especially after southerly storms, snow may last from a few days to a few weeks on the high peaks. Summer droughts are often worsened by strong, dry nor 'west winds (Wilson & Department of Conservation, 1992).

2.2. Geology and Soils

Banks Peninsula was primarily formed by two large volcanoes, Lyttelton and Akaroa which are both now extinct. These extinct volcanoes form the two main harbours in Canterbury, Lyttelton and Akaroa harbours, after part of the caldera walls were breached allowing the sea water to fill up and form the harbours (Wilson, 2009). This forms the basis of the peninsula's extensive parent material type (Figure 2). Soil fertility on the peninsula is mostly medium to high fertility and quite free-draining (Wilson, 2009) (Figure 2).

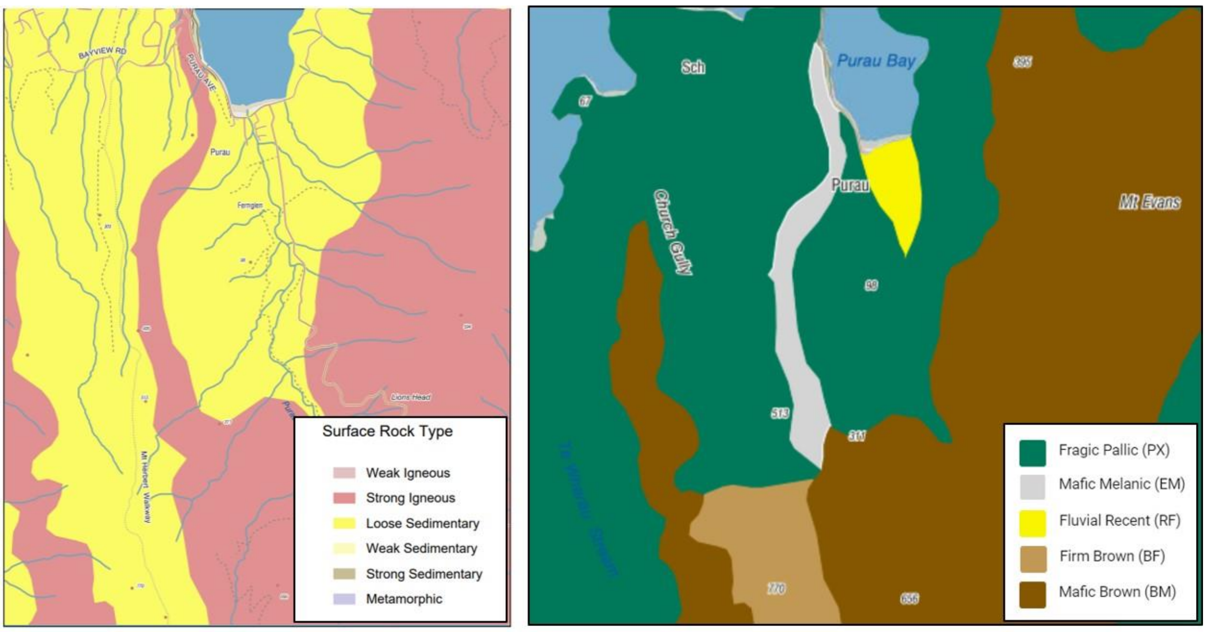

Figure 2: Surface rock type illustrating the volcanic origins (left), and soil types (right). Source: Manaaki Whenua Landcare Research *Our Environment*. https://ourenvironment.scinfo.org.nz/

The Peninsula was first known as Banks Island, named by James Cook after Joseph Banks, a botanist on board the Endeavour (Olgivie, 2007). Originally, the peninsula was an island, and was gradually connected c. 7,000 years ago to the ongoing formation of the Canterbury Plains (Beaumont, Carter & Wilson, 2014). Sand and gravel outwash from the eroding Southern Alps was carried down by large braided rivers, which spread away from the mountains and formed the plains over millennia.[3]

2.3. Vegetation

Before human settlement, the area would have been almost entirely forested with emergent podocarp forest. Abundant tree species included: matai (*Prumnopitys taxifolia*), kahikatea (*Dacrycarpus dacrydioides*), rimu (*Dacrydium cupressinum*), miro (*Prumnopitys ferruginea*), broadleaf (*Griselinia littoralis*), mahoe (*Melicytus ramiflorus*) and pigeonwood (*Hedycarya arborea*). Sub-alpine and alpine species such as snow tussock (*Chionochloa rigida*), fescue tussock (*Festuca novae-zelandiae*), *Dracophyllum* spp. and mountain flax (*Phormium colensoi*) were found on the high bluffs and peaks (Wilson & Department of Conservation, 1992).

Occupying this forested area was an abundance of New Zealand native birds, including kiwi (*Apteryx* spp.), kaka (*Nestor meridionalis*), tui (*Prosthemadera novaeseelandiae*), kereru (*Hemiphaga novaeseelandiae*), moa (Dinornithiformes) and saddleback (*Philesturnus carunculatus*) (Beaumont, Carter & Wilson, 2014). Many of these species are now at risk of extinction or became extinct due to habitat loss, hunting, and introduced mammalian predators.

Around one-third of the forest was removed in the Mount Herbert area when Polynesian settlers came to the area. Much of the remaining forest was removed by European settlers by logging, burning and conversion to pasture for farming. Some very small fragments of the original forest remain today (Wilson & Department of Conservation, 1992; Peart & Woodhouse 2021).

Aerial imagery shows that scrub and tree cover is greater in recent times than the early 1970s (Figure 3). This due to the retirement of some marginal areas, riparian areas being fenced off, restoration plantings of indigenous species, and radiata pine (*Pinus radiata*) production forestry. The Purau catchment is now used primarily for grazing sheep and cattle, pine forestry, with a small settlement.

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[3] For more information, readers are directed to a recent landscape restoration and planning study "*Restoring Te Pātaka o Rākaihautū/Bans Peninsula* by the Environmental Defence Society (Peart & Woodhouse 2021) funded by Environment Canterbury. www.eds.org.nz

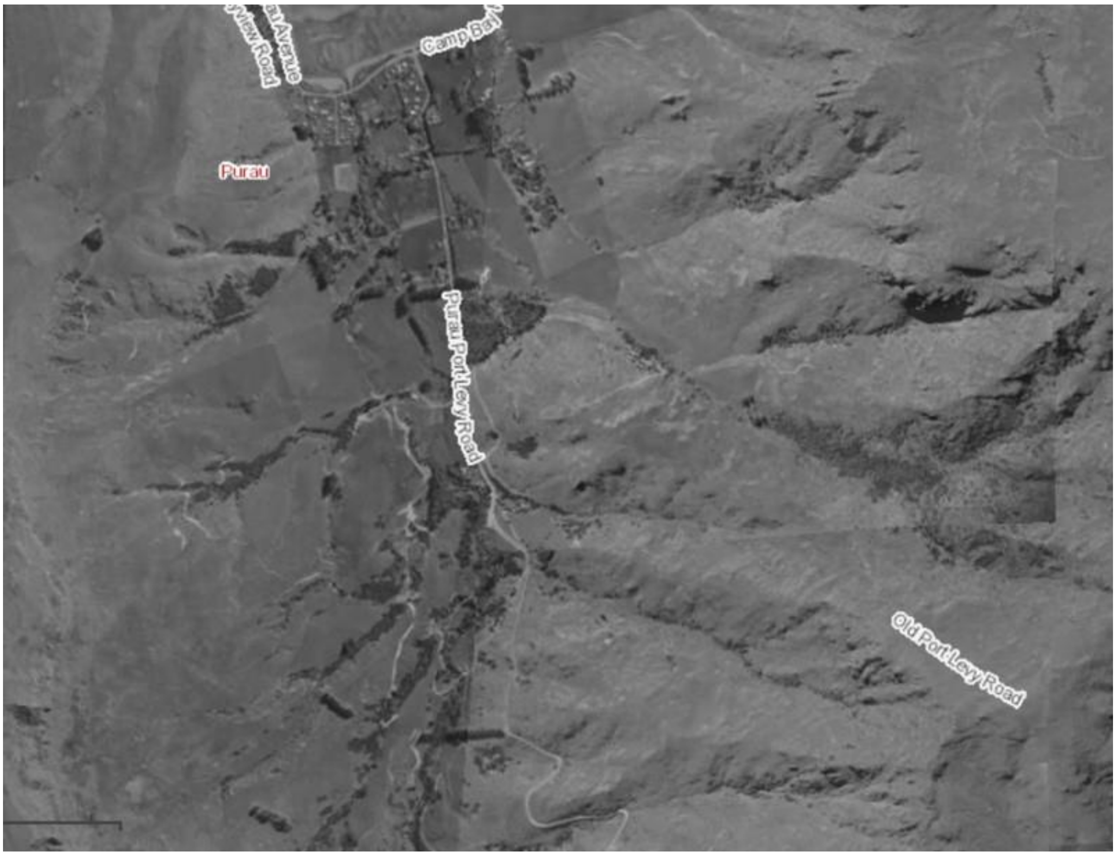


Figure 3: (*Top*) Aerial imagery of Purau catchment vegetation 1970-1974. (*Bottom*) 2018 imagery retrieved 19 February 2021 https://apps.canterburymaps.govt.nz/CanterburyHistoricAerialImagery/

Chapter 3. Overview of Historical Human Influences

3.1 Māori Settlement

Purau Bay is thought to be one of the oldest sites on Te Pātaka o Rākaihautu/Banks Peninsula for Māori settlement. Ovens containing moa bones, stone adzes and necklaces have been found at excavation sites near the beach (Olgivie, 1970). Artefacts excavated from the beach include greenstone and stone adzes identified from the Ngāi Tahu era (Olgivie, 1970). Te Pātaka o Rākaihautu means the storehouse of Rākaihautu as the forests contained an abundance of food (Mahaanui Iwi Management Plan 2013). For a history of tangata whenua relationships with the whenua, ngahere, awa, and moana of the area as shared publicly, readers are directed to the Waitangi Tribunal report on the Ngāi Tahu Treaty Claim (1991).

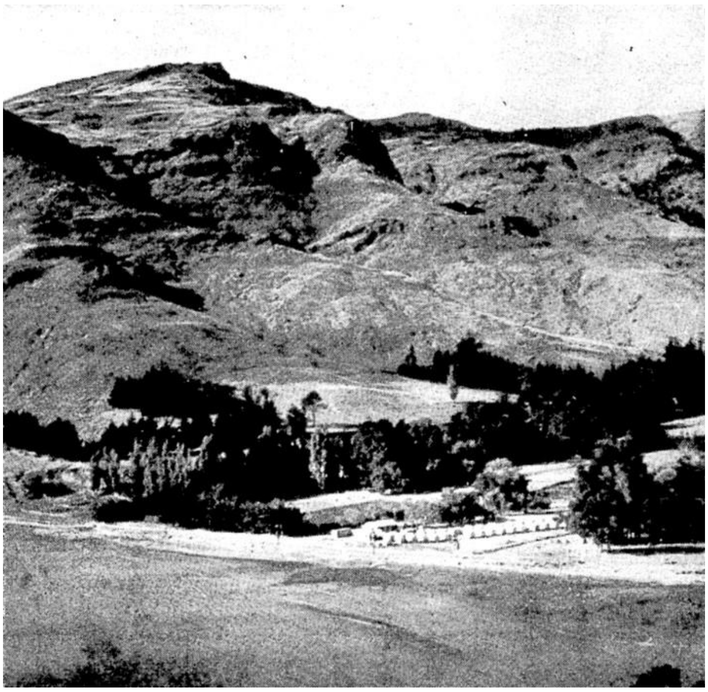
From 1836, whaler ships began to visit the peninsula regularly, Māori traded with the whalers for items such as tools, clothing, food and medicine (Christchurch City Council, n.d). Some Māori men were also able to gain employment on the whale ships (Olgivie, 2007). Along with the employment, whalers also bought alcohol, tobacco, muskets and European diseases (Olgivie, 2007). The Māori population on the peninsula in 1849 was recorded at around 300, and in 1857 the Purau population was recorded at 12 (Christchurch City Council, n.d).

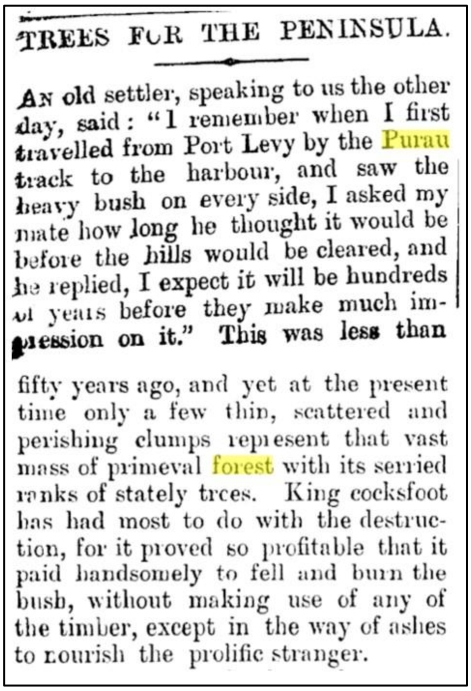
Figure 4: Richard Oliver. The Māori Settlement, Purau Bay, Port Cooper. 1850. Collection of Christchurch Art Gallery Te Puna o Waiwhetū; purchased with assistance from the Olive Stirrat Bequest, 1983. Source: https://christchurchartgallery.org.nz/collection/83-49/richard-aldworth-oliver/the-maori-settlement-purau-bay-port-cooper

3.2. European Settlement

The Greenwood brothers, James, Joseph and Edward, were the first European settlers at Purau Bay in 1843. The brothers planned to squat on the land and James travelled to Australia to organise the purchase of cattle to ship to the Peninsula (The Press, 1945). As they ‘had no legal rights to buy land in the South Island’ (Ogilive, 1970 p23), this caused problems with the local Māori population and the government. After many discussions, the Greenwoods agreed to pay the local Māori a yearly rent of six blankets and printed calico (Ogilive, 1970).

After a robbery of the Greenwood brothers, Edward decided to return home to England. The Purau station was sold in 1847 for £1710, which included the stock, to the Rhodes brothers (The Press, 1945). Joseph Greenwood was lost at sea in 1848 after the whaleboat he was travelling on to Motunau, washed up in pieces near Kaikōura (Nelson Evening Mail, 1932). James travelled to Sydney to purchase stock for a farm the brothers wanted to set up in Motunau, he never returned, assumed murdered as he was carrying money (Ogilive, 1970). George Greenwood arrived in 1864 to settle the family matters (Ogilive, 1970).





TREES FOR THE PENINSULA.

An old settler, speaking to us the other day, said: "I remember when I first travelled from Port Levy by the Purau track to the harbour, and saw the heavy bush on every side, I asked my mate how long he thought it would be before the hills would be cleared, and he replied, I expect it will be hundreds of years before they make much impression on it." This was less than fifty years ago, and yet at the present time only a few thin, scattered and perishing clumps represent that vast mass of primeval forest with its serried ranks of stately trees. King cocksfoot has had most to do with the destruction, for it proved so profitable that it paid handsomely to fell and burn the bush, without making use of any of the timber, except in the way of ashes to nourish the prolific stranger.

Figure 5: (*Left*) Purau Bay and surrounding hills with all native forest felled, 1939. Retrieved: 23 Feb: https://paperspast.natlib.govt.nz/newspapers/CHP19390504.2.129.5?items_per_page=10&query=purau&snippet=true&type=ILLUSTRATION. (*Right*) The destruction of old growth native forests on the Peninsula happened rapidly, as described here in 1900. Retrieved 23 Feb https://paperspast.natlib.govt.nz/newspapers/AMBPA19000710.2.7?items_per_page=50&query=purau+forest&snippet=true

The Rhodes brothers set up a station in Akaroa in 1843 and then started to purchase other land, including Purau, Kaituna and Ahuriri. In 1850, when Lyttelton was being settled, The Rhodes brothers were able to supply the workers with dairy products, vegetables and meat (Ogilive, 1970). Some of the brothers moved south to set up a station near Timaru, while Robert Rhodes remained in Purau to run the peninsula stations (The Press, 1937). From 1866-1874, the station was managed by various people while Robert was in Christchurch managing the family's business matters. In 1874 Robert returned to England after his health declined to seek medical treatment and in the same year Henry Gardiner purchased the Purau Station for 20,000 pounds (Ogilive, 1970; The Star, 1909). Much of the native bush was felled during this time and sown with cocksfoot, with the development of the station (Figure 5). The Gardiner family worked this area for the next 50 years (Ogilive, 1970).

Chapter 4. Sampling Methods

4.1. Study Area

This study took place in Purau Bay and Orton Bradley Park (Figure 1). Sampling was conducted in the middle of January 2021 over two days. The temperature during this time was 13-14 °C with between 0.5 mm and 1.0 mm of precipitation in the 2 days leading up to the sampling, recorded at nearby Cooper's Knob.

The streams selected for this study were Purau stream (-43.639154 S, 172.750120 E) located in Purau Bay, and Te Wharau Stream (-43.654954 S, 172.705582 E), located in Orton Bradley Park, Charteris Bay (Figure 6). Both catchments have pastoral agriculture, primarily grazing for sheep and cattle in the upper and middle areas of the catchment (Figure 7). The lower catchment areas differ with Purau predominantly urban, immediately surrounding the stream. Orton Bradley is a privately owned park which has public facilities and walking tracks in the lower catchment area. Both catchments have areas of exotic tree species, including areas of radiata pine plantations, willows along streamsides, and regenerating native shrub and tree species (Figure 7).

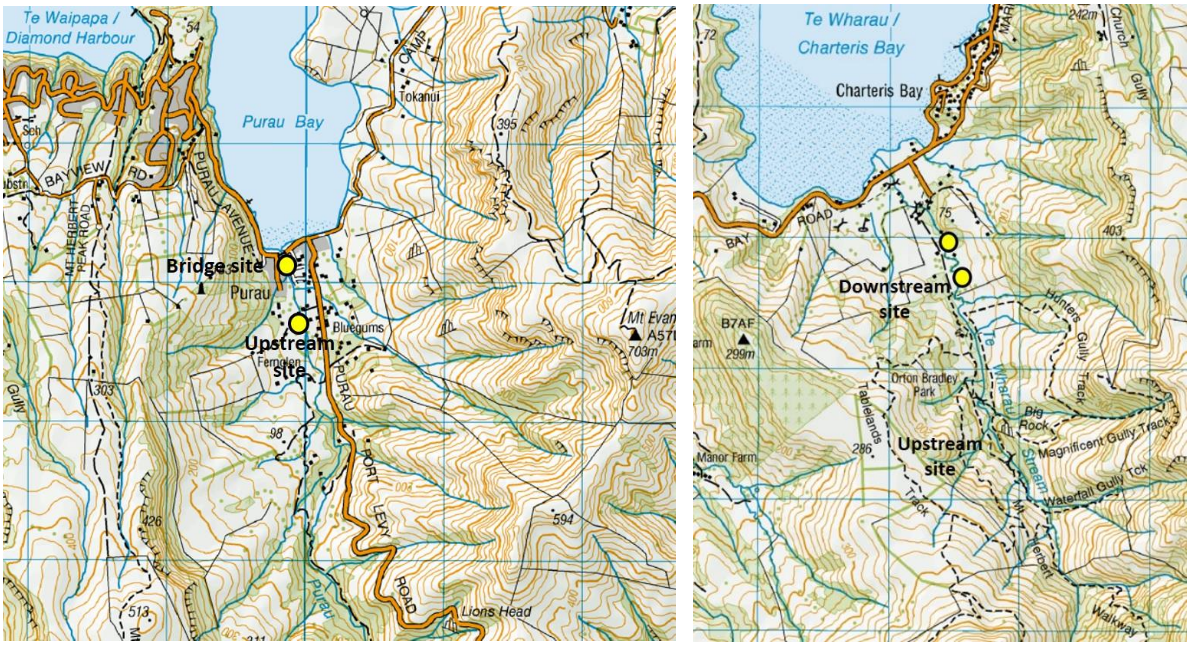


Figure 6: Water quality sampling sites in Purau (*Left*); and Te Wharau Stream (*Right*), January 2021.

Figure 7: Current vegetation patterns in Purau and Te Wharau catchments. Source: Manaaki Whenua Landcare Research's *Our Environment*.

4.2. Materials and Methods

Within each of the four sampling sites, there were three subsampling points along a 50m reach. Sub-sample sites were selected within the 50 m reach. All sites were located under mature tree canopy, either exotic or native species (Figure 9).

Invertebrates were collected using a kick sample with a D shaped net (NIWA, 2020). The net was placed at the selected site, and an area of streambed 80 cm upstream of the net and the width of the net (30 cm) was disturbed. This was done twice at each sampling point along each transect. Samples were sorted as they were taken.

The invertebrates collected from Purau Bay were preserved in 70 % ethanol, with some easy to identify taxa released, such as dobsonfly and smooth cased caddisfly. Invertebrates collected from Orton Bradley were sorted with photographs taken and released back to the stream as per the ranger's instructions.

An estimate of the canopy cover was taken by sight and was taken by the same person throughout to ensure consistency. Substrate composition was estimated, categories used were: boulders larger than 25 cm, large cobbles 12-25 cm, small cobbles 6-12 cm, gravels under 6 cm, sand, silt and woody debris (NIWA, 2020).

A habitat assessment was conducted following the methods used by Environment Canterbury (obtained from A, Barnden, Environment Canterbury) at all four stream areas. This assessment scored features of the habitat in four categories: optimal, suboptimal, marginal and poor. The habitat parameters assessed were "Bank Stability", "Embeddedness/Siltation", and "Sediment Deposition" (Appendix 1).

4.3. Statistical Analysis

Data were recorded, analysed and graphed in Microsoft Excel. Sampling sites were grouped by location and an average was created to show the average for MCI and canopy cover which gave us four representative sites.

The MCI score was calculated using the equation: (Stark, 1985):

$$\text{MCI} = \frac{\text{site score}}{\text{no. of scoring taxa}} \times 20$$

The taxa recorded in each sample were given a score between one and ten. For example, a pollution tolerant snail is given the score of three and a sensitive species such as a stonefly, is given the score of ten. These scores are summed together to give the site score, this score was then divided by the number of scoring taxa in the sample and multiplied by 20.

The substrate index was calculated as follows (McMurtie & Greenwood, 2008):

$$\text{Substrate index} = [(0.7 \times \%\ \text{boulders}) + (0.6 \times \%\ \text{large cobbles}) + (0.5 \times \%\ \text{small cobbles}) + (0.4 \times \%\ \text{pebbles}) + (0.3 \times \%\ \text{gravels}) + (0.2 \times \%\ \text{sand}) + (0.1 \times \%\ \text{silt}) + (0.1 \times \%\ \text{concrete/bedrock})] / 10$$

Figure 8: (*Top left*) Purau Stream Site 1 (Bridge) looking upstream. (*Top right*) Purau Stream Site 2 looking downstream. (*Bottom left*) Te Wharau Stream Site 3 looking upstream. (*Top right*) Te Wharau Stream Site 4 looking downstream.

4.4 Limitations

Limitations for this study included not being able to take invertebrates back to the laboratory from Orton Bradley Park for identification. This information was only found out on the day of sampling even after contacting the park's ranger via email previously. Accessibility of Purau stream was a limitation for this study as most of the land surrounding the stream is privately owned. The sites used for the study were publicly accessible but if more time were allowed, more sites would be beneficial but would involve gaining permission and a site visit up the whole of the stream to determine sampling sites.

Chapter 5. Results

A total of six orders were identified from the collected invertebrates from the two streams. These orders are: Trichoptera (caddisfly), Megaloptera (dobsonfly), Ephemeroptera (mayfly), Diptera (fly), Littorinimorpha (snail) and Oligochaeta (worm). Figure 9 displays the different orders found in Purau Stream at the two locations that were sampled. Site 1 (Bridge) had high numbers of pollution-tolerant species than Site 2 (Upstream). The two Orton Bradley sites were qualitatively similar to Purau Site 2. The MCI scores reflected this pattern, with Purau Site 1 having the lowest MCI, although this was still in the B category (rated as ‘Good’). The other three sites were in the ‘Excellent’ category (Figure 10).

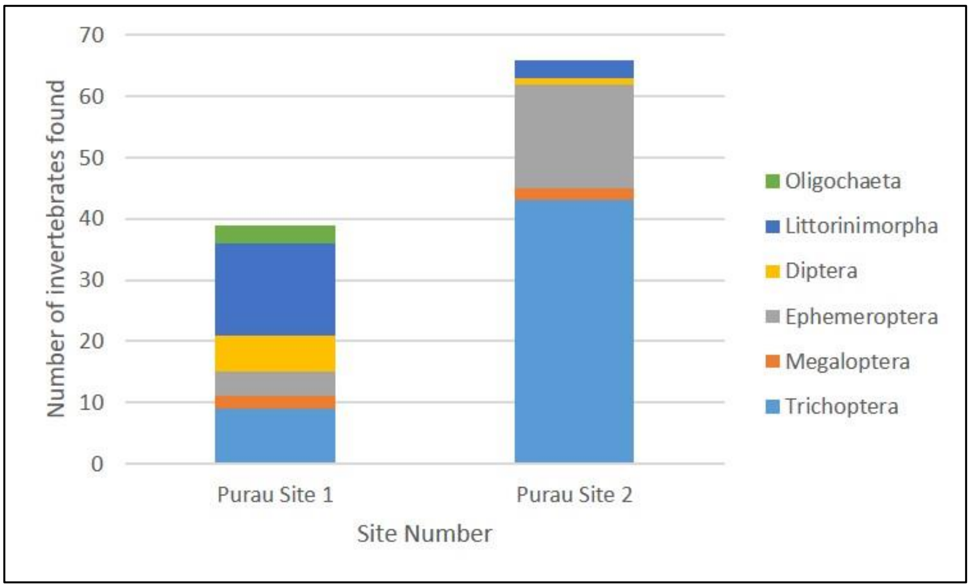


Figure 9: Invertebrate orders identified in the samples from Purau Stream, January 2021.

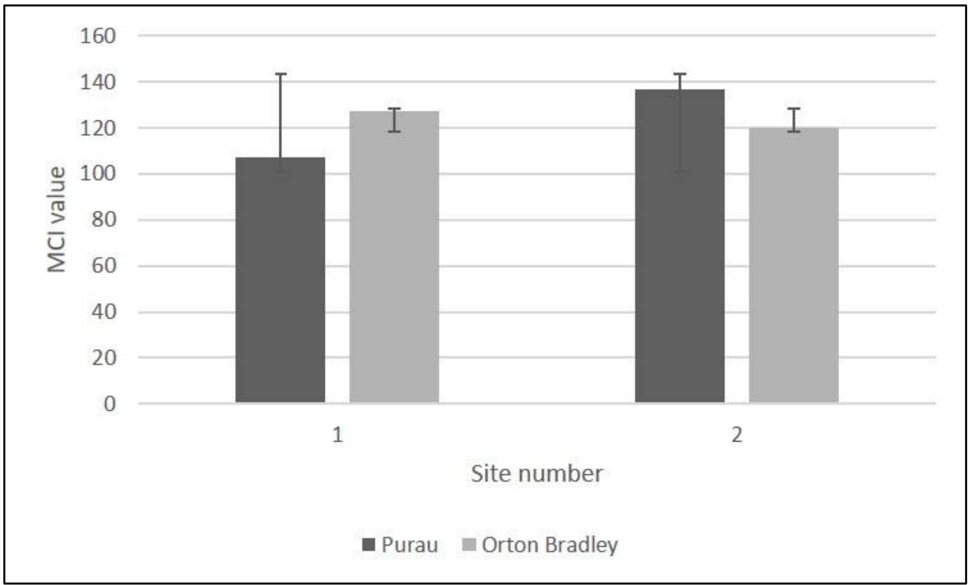


Figure 10: Macroinvertebrate Community index (MCI) values for Purau and Te Wharau Streams.

The MCI results for Purau Site 1 are generally consistent with previous annual sampling at the road bridge, albeit a little lower than most of the previous years (Figure 11). Annual data analysis for Purau Stream also includes median taxonomic richness from the last 5 years and median Ephemeroptera (mayfly), Plecoptera (stonefly) and Trichoptera (caddisfly) (%EPT) from the last 5 years. Taxonomic richness for this site is currently recorded at 26 and %EPT is 40.7 (LAWA, n.d). Although the taxonomic richness is on the higher side, the percentage of sensitive species used to calculate the %EPT is on the low side. The %EPT is the percentage of mayfly, stonefly and caddisfly present in a sample; a low percentage can indicate poor stream health as the rest of the sample is made up of pollution tolerant species. Taxonomic richness at Purau site 1 was recorded as 8 and %EPT calculated as 37.5. Purau site 2 taxonomic richness also recorded as 8 and %EPT calculated as 62.5.

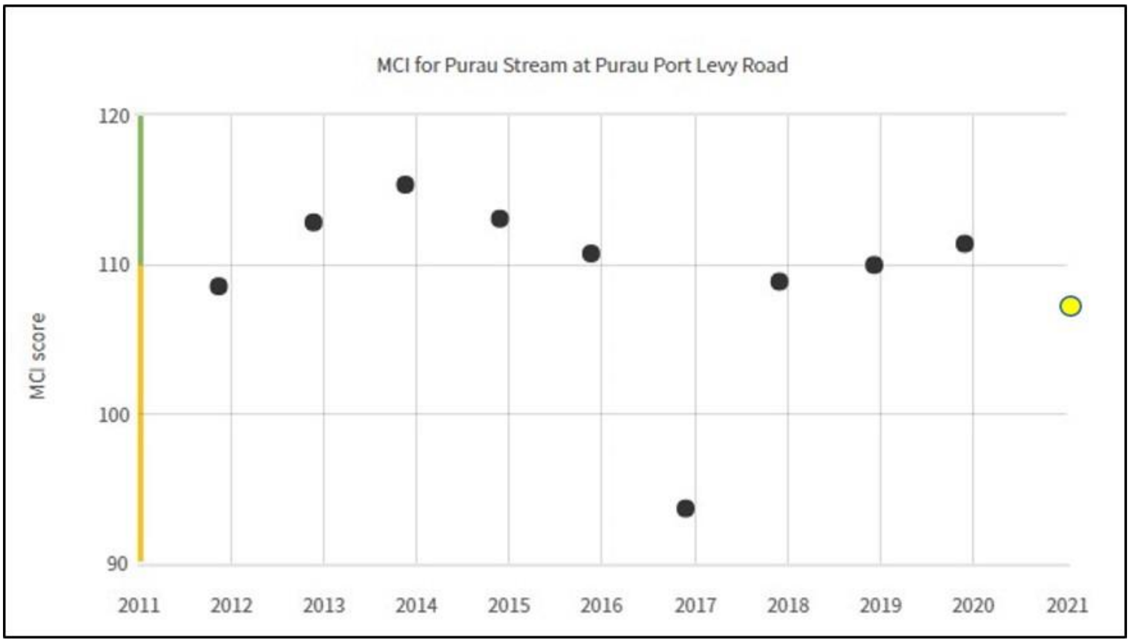


Figure 11: Macroinvertebrate Community index (MCI) values for Purau Stream at the Puraru-Port Levy road bridge site from 2011-2021. Environment Canterbury data from www.lawa.org.nz The MCI calculated from this study is depicted as a yellow circle.

The mean of the substrate composition at each of the four sites is shown in Figure 13. The higher the number, the higher the percentage of large cobbles or boulders at that site. Orton Bradley site 1 had the highest mean at 5.8, with the lowest at Purau site 2 with 5.2. This is unlikely to be a meaningful difference in an ecological sense, given the similarity in the habitats depicted in Figure 9. Moreover, the MCI scores do not show a similar pattern between sites. In other words, Purau Site 1 did not have the highest or lowest mean score that would suggest the small differences in the index scores were significant in ecological habitat terms.

The results from the qualitative assessment of canopy cover (Figure 13) also did not suggest differences in assessed cover were an explanatory factor in the MCI patterns observed. Purau Site 1 and Te Wharau Site 4 (Orton Bradley Site 2) had similar cover at >60%, yet the MCI scores differed markedly (Figure 10). The MCI scores of Purau Site 2 and Te Wharau Site 3 (Orton Bradley Site 1) were similar to Te Wharau Site 4, yet canopy cover for Purau Site 2 was much lower at 40% (Figure 13). The site photos show all sites had shading from intact tree cover (Figure 8).

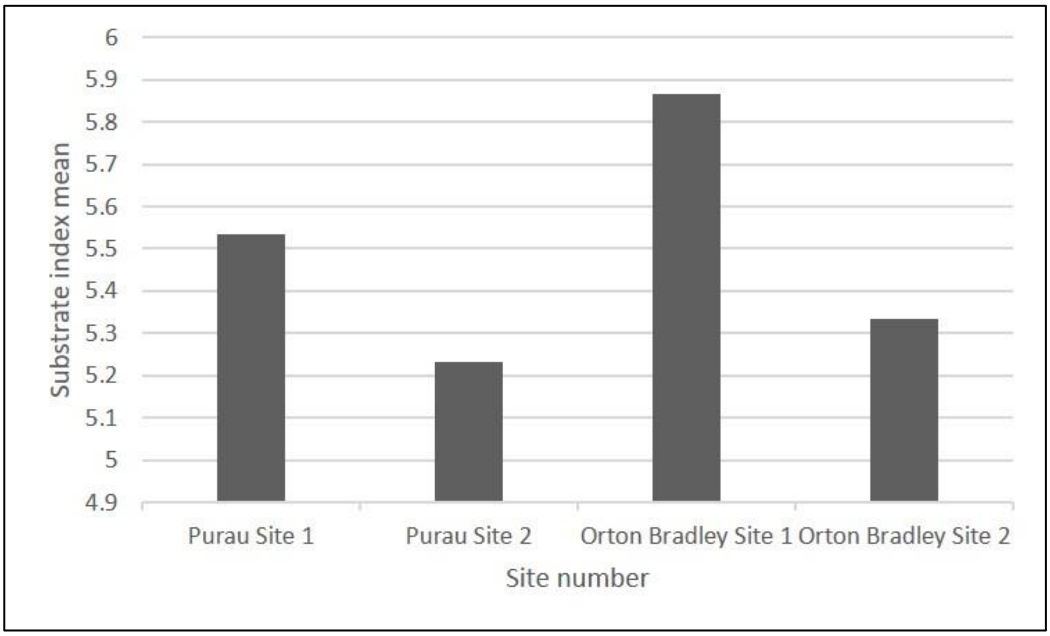


Figure 12: Substrate index mean for all sites.

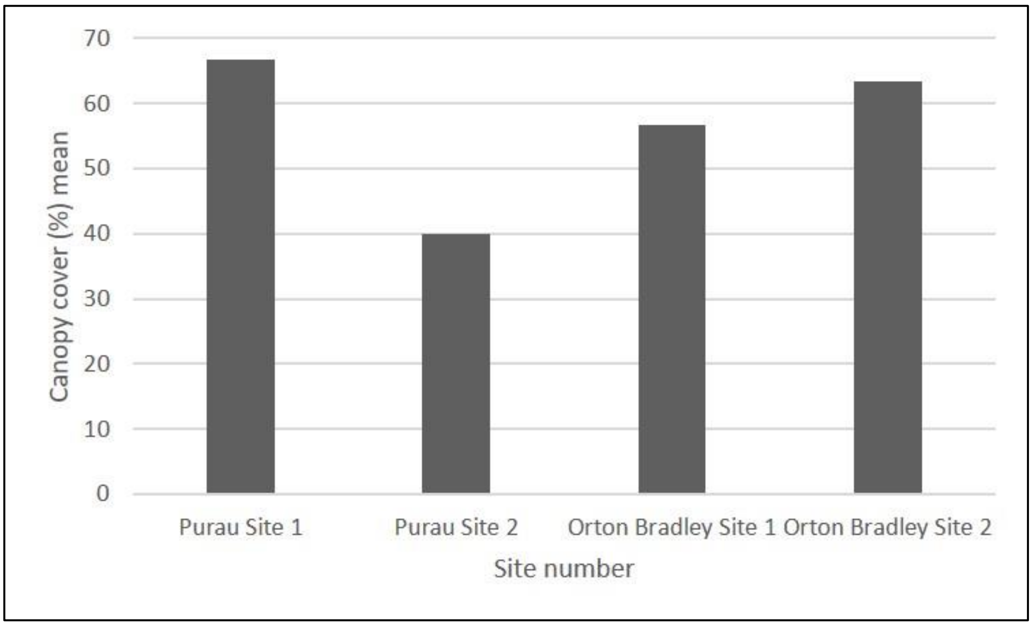


Figure 13: Qualitative assessment of mean canopy cover (%) for all sites.

Erosion of the stream banks was recorded in the habitat assessment with the Te Wharau (Orton Bradley) sites scoring higher than the Purau sites. Both left and right banks were scored separately at each sampling site. Orton Bradley site 1 had a suboptimal score for both banks – that is moderately stable with small areas of erosion. The streambanks at Orton Bradley site 2 were assessed as suboptimal and marginal (moderately unstable with 30-60% of the bank area with small areas of erosion). The situation at Purau site 1 was marginal for both banks; and assessed as marginal and poor at site two; where poor is unstable, with many eroded areas and erosional scars over most of the banks.

The visibility of sediment in the streams differed between the sites, with Purau site 1 in the urban area carrying the highest amount of streambed sediment. In the habitat assessment for sediment deposition, Orton Bradley site 1 and Purau site 2 scored suboptimal (slight deposits observed), Orton Bradley site 2 scored marginal (moderate amounts of silt deposition) and Purau site 1 scored poor (heavy deposits of fine material).

The embeddedness of siltation around boulders, cobbles, and gravel also differed between the sites. Orton Bradley site 1 and Purau site 2 were assessed as suboptimal (fine sediment surrounding 30-50% of the coarser material). Orton Bradley site 2 scored marginal (>50-75% surrounding); and Purau site 1 scored poor (the coarser material was surrounded by fine sediment)

Chapter 6. Discussion

Results from the macroinvertebrate community index (MCI) suggested that environmental conditions at the road bridge site at Purau was different to the other sites. The other Purau and the two Te Wharau stream sites more closely resembled each other in MCI, with more abundant pollution sensitive species such as smooth cased caddisfly, helix caddisfly, mayfly, dobsonfly, cranefly and bark caddisfly. In contrast, Purau bridge (Site 1) had a greater abundance of pollution-tolerant species; such as polychaete worms, snails, and non-biting midges. Snails and non-biting midge are found in degraded and polluted waterways elsewhere (NIWA, 2020).

Notwithstanding the lower MCI score at Purau Site 1, it is still assessed as 'Good' in the accepted MCI classification system (www.lawa.org.nz). However, it would be prudent to undertake sampling of other water quality analytes, such as bacteria and nutrients, to determine the likely cause(s) of the relative deterioration. This may then lead to a targeted investigation to identify and manage the source of the stressors.

This is because it is unlikely that subtle differences in assessed canopy cover and substrata are plausible explanatory factors. All sites had canopy cover with large mature exotic trees such as willow, with native trees/shrubs and smaller exotic trees in the understorey. Aquatic invertebrates primarily prefer lower instream temperatures, which are influenced by canopy shading that keep a cooler temperature more consistently than if the stream was in full sun (Collier, 1995).

The high water quality in the other sites sampled is reflected in the presence of mayflies and caddisflies. If environmental conditions were to deteriorate, these species will start to decline and be replaced with more snails, worms and midges. Other organisms such as dobsonflies and fish feed on mayflies and caddisflies; so a decline or loss of these prey species may influence the resilience of the food web.

Substrate composition is one of the most important factors for invertebrate composition, as the substrate provides habitat and food sources in the stream environment (Bourassa and Morin, 1995). The substrate index mean was very similar for all sites. Purau sites one and two were 5.5 and 5.2. With the Orton Bradley sites one and two at 5.8 and 5.3. Purau site 1 had a visibly noticeable amount of sediment settled into the gaps of cobbles compared to the other sites, but overall the substrate composition was similar at all sites, with a mixture of boulders, large cobbles, small cobbles, gravels and silt (Figure 10).

There are a number of environmental factors which could cause a change in substrate composition and thereby affect stream health, such as a loss of riparian vegetation, or catchment land use activities. For example, clearfell harvesting of radiata pine has been shown to deposit large volumes of fine sediment in waterways from soils high in clay content (O'Loughlin, 1979), such as those found throughout in the catchment. Sediment entering waterways is a natural process, however high levels of sediment from human activities can be damaging to freshwater ecosystems (NIWA, n.d). When excessive amounts of sediment enter a waterway, it starts to settle in the gaps between rocks in the substrate. These gaps are important habitats for aquatic invertebrates and can decrease the abundance of sensitive species. This is because sediment fills up the gaps between cobbles, preventing invertebrates seeking shelter between and under the cobbles. A literature review completed by Davies-Colley et al. (2015) of many studies from around the world, highlighted that invertebrate abundance decreases as sediment increases. Wood et al. (2005) documented that sensitive species were absent from sediment over 10 mm but some were able to survive in less than this. The areas of erosion observed upstream in Purau Stream could be a contributing factor to the higher sediment load downstream when the flow of the stream is higher or in flood

Conclusion

Overall, the health of Purau Stream and Te Wharau stream are in good health as indicated by their MCI values, however it is clear that Purau stream has degraded in quality as it reaches the urban area. This could be due to impacts from the surrounding land uses. It is reassuring to see that the two streams are in relatively good condition, however work needs to continue to restore the waterways to assure that the ecological health is maintained, rather than degrades. Actions such as riparian plantings, fencing waterways, limiting fertiliser and pesticide use where possible can all help with nutrient run-off and erosion control to contribute to better stream health. Harvesting of the pine plantations will also need to be managed with care to prevent run-off into the streams and out into Lyttelton Harbour/Whakaraupō.

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Appendix

Table 1: Assessment criteria for habitat parameters: Bank Stability; Sediment Deposition; and Embeddedness/Siltation.

Habitat Parameter	Category			
	Optimal	Suboptimal	Marginal	Poor
Bank Stability (score each bank)	Banks stable; evidence of erosion or bank failure absent or minimal; little potential for future problems. <5% of bank affected.	Moderately stable; infrequent, small areas of erosion mostly healed over. 5-30% of bank in reach has areas of erosion.	Moderately unstable; 30-60% of bank in reach has areas of erosion; high erosion potential during floods.	Unstable; many eroded areas; "raw" areas frequent along straight sections and bends; obvious bank sloughing; 60-100% of bank has erosional scars.
27 SCORE ___ (LB)	Left Bank 10 9	8 7 6	5 4 3	2 1
28 SCORE ___ (RB)	Right Bank 10 9	8 7 6	5 4 3	2 1

Habitat Parameter	Category			
	Optimal	Suboptimal	Marginal	Poor
36. Sediment Deposition	Little or no enlargement of islands or point bars and less than 5% of the bottom affected by sediment deposition.	Some new increase in bar formation, mostly from gravel, sand or fine sediment; 5-30% of the bottom affected; slight deposition in pools.	Moderate deposition of new gravel, sand or fine sediment on old and new bars; 30-50% of the bottom affected; sediment deposits at obstructions, constrictions, and bends; moderate deposition of pools prevalent.	Heavy deposits of fine material, increased bar development; more than 50% of the bottom changing frequently; pools almost absent due to substantial sediment deposition.
SCORE	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1

Habitat Parameter	Category			
	Optimal	Suboptimal	Marginal	Poor
35 Embeddedness/Siltation	Gravel, cobble, and boulder particles are 0-25% surrounded by fine sediment. 5 10 15 20 25%	Gravel, cobble, and boulder particles are 30-50% surrounded by fine sediment. 30 35 40 45 50 %	Gravel, cobble, and boulder particles are 55-75% surrounded by fine sediment. 55 60 65 70 75 %	Gravel, cobble, and boulder particles are more than 75% surrounded by fine sediment. 80 85 90 95 100 %
SCORE	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1

Table 2: MCI scores from samples taken in Purau Stream, Purau Bay and Te Wharau Stream, Orton Bradley Park, January 2021.

Site Number	MCI Score	Site Number	MCI Score
Purau Site 1 Sample a	113	Orton Bradley Site 1 Sample a	108
Purau Site 1 Sample b	110	Orton Bradley Site 1 Sample b	126
Purau Site 1 Sample c	100	Orton Bradley Site 1 Sample c	148
Purau Site 2 Sample a	143	Orton Bradley Site 2 Sample a	144
Purau Site 2 Sample b	148	Orton Bradley Site 2 Sample b	104
Purau Site 2 Sample c	120	Orton Bradley Site 2 Sample c	113

Table 3: Interpretation of MCI values (from Gray, 2013)

Interpretation	MCI
Clean water	> 120
Doubtful quality of possible mild pollution	100–119
Probable moderate pollution	80–99
Probable severe pollution	< 80

Table 4: Species list from Purau sites 1 and 2

	Purau Site 1		Purau Site 2	
Megaloptera	dobsonfly	2	dobsonfly	3
Trichoptera	smooth cased caddis	3	smooth cased caddis	36
	stick caddis	5	stick caddis	4
			helix caddis	15
			free-living caddis (Psilochorema)	1
Oligochaeta	worms	3		
Littorinimorpha	snails	15	snails	5
Ephemeroptera	mayfly (Deleatidium)	4	mayfly (Deleatidium)	17
Diptera	cranefly	1	non-biting midge	1
	non-biting midge	5		

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